Before the

FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendment of the Commission's Rules	)	GN Docket No. 12-354
with Regard to Commercial Operations in the	)	
3550-3650 MHz Band	)	
To: The Commission	)	

COMMENTS OF IEEE DYNAMIC SPECTRUM ACCESS NETWORKS STANDARDS COMMITTEE (DYSPAN-SC) ON LICENSING MODELS AND TECHNICAL REQUIREMENTS IN THE 3550-3650 MHZ BAND

The IEEE DySPAN Standards Committee (DySPAN-SC) hereby submits its Comments on the above-captioned Proceeding. The document was prepared and approved unanimously by the 1900.5 Working Groups within the DySPAN-SC[-1].

The IEEE DySPAN-SC is the leading consensus-based industry standards body for Dynamic Spectrum Access Networks (DySPAN), and has the following technical scope:

- dynamic spectrum access radio systems and networks with the focus on improved use of spectrum,
- new techniques and methods of dynamic spectrum access including the management of radio transmission interference, and
- coordination of wireless technologies including network management and information sharing amongst different dynamic spectrum access radio networks.

We appreciate the opportunity to provide these comments to the Commission.

Introduction

1. The IEEE DySPAN Standards Committee commends the Commission for its work in soliciting input focused on sharing between Federal and non-Federal systems in the 3550-3650 MHz band.

[1] This document represents the views of the IEEE DySPAN-SC. It does not necessarily represent the views of the IEEE as a whole or the IEEE Standards Association as a whole.

2. The IEEE DySPAN-SC strongly believes that dynamic spectrum access (DSA) technologies and techniques have the potential to enable more efficient use spectrum resources. The DySPAN-SC further believes that the benefits of the dynamic spectrum access techniques requires a regulatory framework that will encourage business development of products and services that utilized advanced DSA technologies. The acceptance of these advanced technologies by both the business and regulatory communities is dependent on DSA standards developed by international Standards Development Organizations (SDOs) such as the IEEE DySPAN-SC. Thus, the regulatory community, the wireless industry, and SDOs must work in close harmony to achieve the spectrum efficiency benefits associated with DSA radio systems and networks.

3. The work being conducted under the IEEE 1900.5 working group, Policy Language and Architectures for Managing Cognitive Radio for DSA Applications is directly applicable to sharing in the 3550-3650 MHz band. The newly established P1900.5.2 working group is standardizing a method for modeling spectrum consumption. This work should be considered as a core technology of the Spectrum Access Systems (SAS) proposed in the Notice of Proposed Rulemaking (NPRM) for the 3.5 GHz band.[2] While this response centers around the work being completed by the P1900.5.2 working group, the DySPAN-SC working group encourages industry and Federal/non-Federal sectors to identify further areas for standardization, identify the appropriate SDOs to pursue those areas, and start working groups.

4. In the text below, the DySPAN-SC identifies solutions provided by 1900.5.2 to the technical issues listed in FCC 13-144. [3] It describes the SAS architecture 1900.5.2 enables. It describes how SCM enable a much more versatile spectrum management. It identifies how these solutions may enable other licensing, leasing, and marketing models.

Description of the Spectrum Consumption Modeling (SCM) standards work

5. The IEEE DySPAN-SC P1900.5.2 working group seeks to standardize an approach to model spectrum consumption called spectrum consumption models (SCMs) and the attendant computation methods and algorithms to arbitrate compatibility among these models. SCMs are used to capture the boundaries of RF spectrum use by all types of RF devices and systems of RF

[2] See Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band,GN Docket No. 12-354, Notice of Proposed Rulemaking, 27 FCC Rcd 15594 (2012) (NPRM or 3.5 GHz NPRM).
[3] Commission Seeks Comment on Licensing Models and Technical Requirements in the 3550-36550 MHz Band, GN Docket No. 12-354, Notice of Proposed Rulemaking, 27 FCC (2013)

devices. These models enable Model-Based Spectrum Management (MBSM), which is spectrum management executed through the creation and exchange of SCMs. MBSM allows distribution of the spectrum management problem where spectrum users can model their use of spectrum independent of other users and place those models in the MBSM system where the common algorithms arbitrate compatibility. These models are machine readable and serve as a means to convey RF spectrum authorizations, constraints, and behavioral requirements to spectrum dependent systems (SDSs). SCMs could be a core technology of any future national Spectrum Access System (SAS).

6. The IEEE DySPAN-SC P1900.5.2 working group has just started this work. It will be based on concepts in a work of The MITRE Corporation.[4] MITRE anticipates that it will publish the next version of its Model Based Spectrum Management, Part 1 Modeling and Computation Manual in December 2013. This manual provides a complete definition of a modeling approach. This document will be the basis of the first version of the 1900.5.2 standard. In addition, MITRE has implemented many of the computational methods in a MATLAB prototype to validated their efficacy. Based on this foundational work, the work group's goal is to complete this standard by January 2015.

Description of SCM

7. SCMs capture the boundaries of spectrum use by capturing the key characteristics of RF systems and phenomena that determine spectrum use. Currently the modeling method uses 12 construct elements that can collectively capture transmission power, spectral emissions, receiver susceptibility to interference, intermodulation effects, propagation, antenna effects, location (both fixed and mobile), time of use, and radio behaviors that enable compatibility. These construct elements also capture the certainty of what is modeled.

8. SCMs are complemented with defined methods for arbitrating the compatibility between models. A MBSM system is thus capable of managing coexistence of multiple types of users. Models can be made of any type of system that uses the RF spectrum and so compatibility can be managed among types of users differentiated by the purpose or service of their spectrum use, e.g., the radio location service of radar and the land mobile radio service of broadband. These methods support arbitrating compatibility based on both noise limited and interference limited sharing criteria.

[4] Stine, J.A. and Schmitz, S., MITRE Technical Report, "Model-Based Spectrum Management, Part 1: Modeling and Computation Manual," http://www.mitre.org/sites/default/files/pdf/11_2071.pdf.

9. The SCM data schema is narrowly focused on spectrum consumption. It does not capture user identities, RF component nomenclatures, model numbers, equipment capabilities or operational mission descriptions. Rather it provides an assortment of constructs that attempt to convey spectrum use boundaries alone. The schema may be combined with other schema to add the data elements necessary for a particular business process. This separation allows multiple spectrum management domains to communicate spectrum use to each other without the requirement that they agree to any particular data elements of the business processes which might contain information they do not want to share outside their own domain. Additionally, it is possible to convey spectrum use boundaries of systems while obfuscating the particulars of the systems and their operational missions. A SAS can be built without the requirement to store sensitive information. This benefits both government users who do not want to reveal their operations or the capabilities of their equipment and commercial users who want to avoid revealing proprietary and sensitive information about the deployment of their systems.

10. In the subsequent sections we first describe how the SCM resolve the particular technical issues identified in the Commission's request for comments. We build from this discussion to propose an anticipated evolution of the architecture of the future SAS and finally anticipate the opportunities this architecture provides for additional means for licensing and managing spectrum access to those suggested in the request and for managing bands.

Resolving Technical Issues

11. The request correctly states that "the effectiveness of dynamic spectrum sharing depends on the proper applications of the interference mitigation and spectrum management techniques for operating in the shared band." This is the particular function of MBSM using SCM. The purpose of the models is to capture the electromagnetic radiation that systems emit and the susceptibility of systems to interference by other system's electromagnetic emissions. Given the envisioned system where the spectra encompassed in licenses are conveyed with models and the use of spectrum is captured in models, each additional use can be evaluated for compliance with an associated license or lease by applying the compatibility computation methods that accompany the SCM modeling approach. Further, when interference is declared, databases can use the models to identify the most likely cause and take action to mitigate the interference. This can include revising the authorization to the systems that are likely causing the interference.

12. The SCM concept is particularly well suited in creating an *acceptable interference environment*. All SCMs capture the interference limits of the systems they model. These limits

are consistent with the vision of the FCC's Technical Advisory Council's for harm claim thresholds.[5] The spectrum consumption modeling methods provide a means to identify the acceptable power spectral flux density of interference as well as the power spectral flux density of emissions and their dependence on propagation. All types of systems can be modeled and there is a common approach for resolving whether the models indicate that one system will violate another's interference limits.

13. The SCM concept provides *technical flexibility*. It is intended that any type of system can be modeled and so MBSM can also support the management of interference among very disparate systems including between radars and broadband communications. Modeling supports collaborative management where spectrum users of very different enterprises can communicate their spectrum use to each other without having to share sensitive information about the systems that are using the spectrum or of the operations using these systems. This story is well described in the DySPAN-SC response to the 3.5 GHz NPRM.[6]

SAS Architecture Evolution[7]

14. The goal of spectrum consumption modeling is that it become a loose coupler for spectrum management in the same way as the Internet Protocol (IP) is a loose coupler for networking. Loose coupling occurs at the intersection of a large set of systems and allows them to interoperate and to be integrated. Figure 1 is a bowtie diagram that illustrates the loose coupler role of spectrum consumption models (SCMs). At the top layer SCMs provide a means for systems that collectively perform spectrum management to convey to each other their understanding of spectrum consumption and to spectrum users boundaries of available spectrum and constraints to it use. At the bottom layer, it allows RF systems that use the spectrum to compute coexistence and improve their usage of spectrum. SCMs are machine readable and thus provide a means for spectrum management systems to convey spectrum usage rights to RF systems. It also allows RF systems to express their spectrum needs and to convey the actual spectrum they are using to spectrum management systems. By standardizing spectrum consumption modeling, we create the

---

[5] *See* FCC Technological Advisory Council, Receivers and Spectrum Working Group, Interference Limits Policy -The Use of Harm Claim Thresholds to Improve the Interference Tolerance of Wireless Systems, White Paper(February 6, 2013), available at: http://transition.fcc.gov/bureaus/oet/tac/tacdocs/WhitePaperTACInterferenceLimitsv1.0.

[6] See Comments of IEEE Dynamic Spectrum Access Networks Standards Committee (DYSPAN-SC) on Commercial Operations in The 3550-3650 MHZ Band, available at: https://mentor.ieee.org/dyspan-sc/dcn/13/sc-13-0014-02-MISC-p1900-5-response-to-fcc-12-148.pdf

7 This section was taken with a small amount of modification from a paper recently submitted for consideration for presentation at the 2014 IEEE DySPAN Conference. D. Swain-Walsh, M. Sherman, J. Stine, and H. McDonald, " IEEE 1900.5 Enabled Whitespace Database Architecture Evolution," November 2013.

conditions for there to be innovation in the adjacent layers, in this case dynamic and policy-based spectrum management, and RF systems and devices that can access spectrum dynamically.

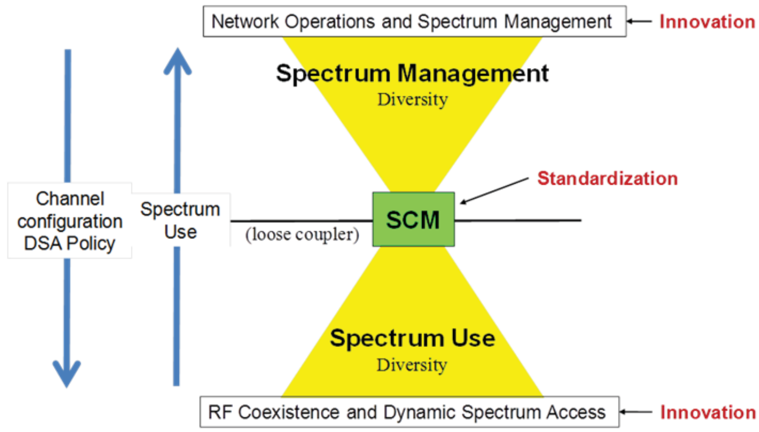

Figure 1. The role of SCMs in future spectrum management

15. The timeliest applications of the products of this standard will be in dynamic spectrum management. SCMs can convey both the required protection to incumbent users and the spectrum requirements of new users. SCMs provide a means for specifying spectrum consumption without requiring the revelation of system details. Combining these models with a common tractable means for computing compatibility allows multiple spectrum managers to collaborate in managing coexistence by simply sharing models. The SCM allow different communities to collaborate in the use of spectrum but hold close operational and technical details of their systems. It is well suited for the spectrum sharing using databases as proposed by the Presidential Committee of Advisors on Science and Technology (PCAST) in their 2012 report[8] on spectrum sharing between federal and commercial spectrum users.

16. The SCMs provide a means to define quanta of spectrum that can be traded and so commoditize spectrum. Spectrum markets of the future can use SCM to request spectrum, to identify available spectrum and to negotiate spectrum sharing. In a negotiation, parties would iteratively exchange models until they arrive at a set that are compatible. These markets can be built upon and use the methods of database managed spectrum sharing.

17. The spectrum consumption modeling methods only capture the boundaries of spectrum use. They can combine with other schemata to support a variety of business processes and architectures. These architectures can run the gamut of spectrum management visions from the

[8] PCAST, Report to the President: Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth (rel. July 20, 2012) (PCAST Report) at 33-38, 107-115, available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.

creation of better standalone spectrum management tools, collaborative management environments within enterprises, database managed sharing among enterprises, spectrum markets, negotiation of spectrum sharing, and delivery of policy to RF systems for autonomous selection of spectrum.

18. SCM can change the nature of spectrum management tools. Figure 2 provides a simple diagram of the change. Currently spectrum management tools collect data about systems and have algorithms that assist in making assignment decisions. The tools are complemented with custom algorithms designed to support solving specific reoccurring spectrum management problems. Spectrum management, however, is tool centric and requires manager judgment. To consider new systems requires the collection of detailed data about those systems and the spectrum manager using the tool needs to learn how to treat the system in analysis. The advancement provided by using SCM is first seen in a change of process. The first step in analysis is the creation of the model for each particular system's use of spectrum. Next, is the use of standardized algorithms, also referred to as tools in the diagram, which operate on collections of SCMs to accomplish spectrum management tasks. Within tools, the intermediate creation of SCMs preserves the judgment of the manager on the use of the spectrum and it supports analysis with any other modeled system.

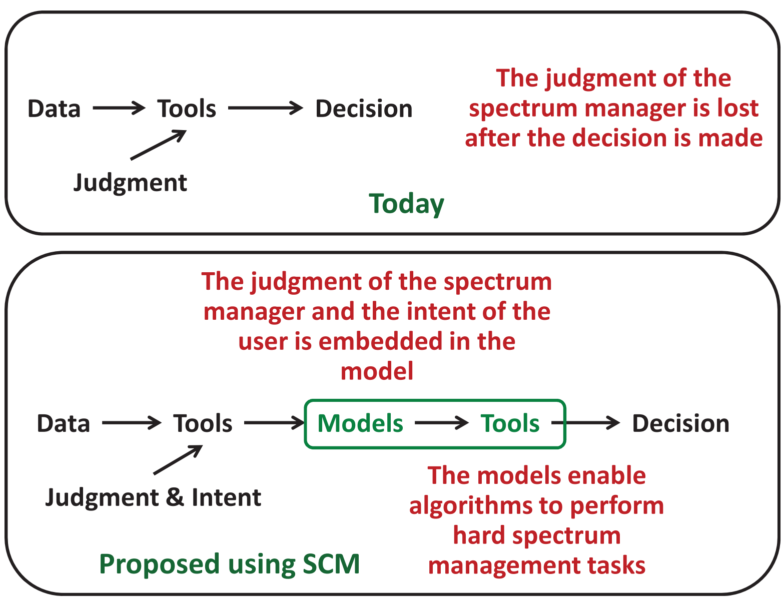

Figure 2. Alternative analysis and tools

19. Using SCMs as the basis of spectrum management decisions, changes the architectures that are used for distributed spectrum management. Figure 3 illustrates the difference. With data centric systems, centralized tools are accessed for performing spectrum management tasks. This

approach requires the tool to be a repository of detailed data of all the systems being managed and spectrum assignments. It requires the tools and the managers to be aware of system nuances relevant to their coexistence with other systems. However, this architecture makes spectrum management hard because of resistance to revealing details about all systems and their uses and the complexity of performing spectrum management based on first principles. It is unrealistic to expect managers to understand all the nuances that are relevant in doing coexistence analysis. It is unrealistic to automate the analysis for all system interactions in these tools. We see in the alternative enabled by SCM, system details do not need to be placed in a central repository but can be held close within each spectrum management enterprise. Distributed spectrum management is accomplished by sharing SCM. Each enterprise can specialize in knowing the details of their systems and the methods for building SCM of their use of spectrum. The methods for arbitrating compatibility are all standardized and based on the SCM and so it is not necessary for the spectrum managers of the enterprises to either know the performance and operating details of the other systems or the specific nuances of their ability to coexist.

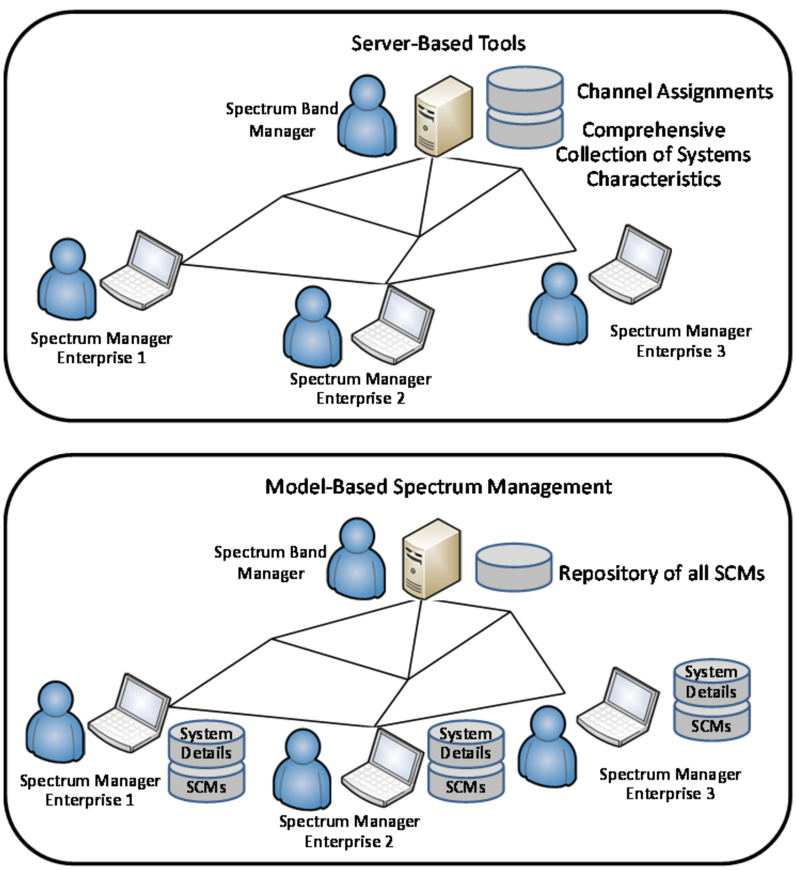

Figure 3. Alternative spectrum management architectures

20. This advancement in distributed spectrum management can also change the nature of spectrum management. With centralized systems, spectrum management by nature seeks

persistent solutions, solutions that last until a new problem demands new analysis that dictates something else be done. The use of SCMs encourages the revelation of operational use of spectrum into the future, which includes spatial and temporal changes in use. Resolution in these dimensions, in turn, encourages less greedy spectrum assignments. The use of SCMs to define spectrum use and the full automation of arbitrating compatibility among SCMs remove much of the burden of dynamic management. SCMs that reveal the changing use of spectrum into the future would allow algorithms that operate on collections of models to reveal opportunities to reuse spectrum.

21. These characteristics advance database spectrum management in several ways. Figure 4 illustrates the differences. In existing spectrum management systems, the role of the database is to arbitrate entry of new users based on their compatibility with incumbents. RF devices are certified to operate in a way that databases understand and regulation defines the approach to compute which channels are available to those device based on device location and established "contours" of incumbent use. The databases do not manage secondary coexistence. Using SCM can change this management in two ways. First, assuming devices provide or the database can build an SCM of their spectrum use, compatibility can be computed and so coexistence can be managed. Second, since compatibility is based on using SCM, regulators no longer need to define the contours. Incumbent users can convey directly to databases their spectrum use with SCMs and these would be sufficient to serve as contours for a database to determine if new uses would be compatible. This outcome also holds true in an environment with multiple database administrators. So long as all databases have a common set of SCMs of spectrum users they will arrive at the same conclusions on the admission of new users.

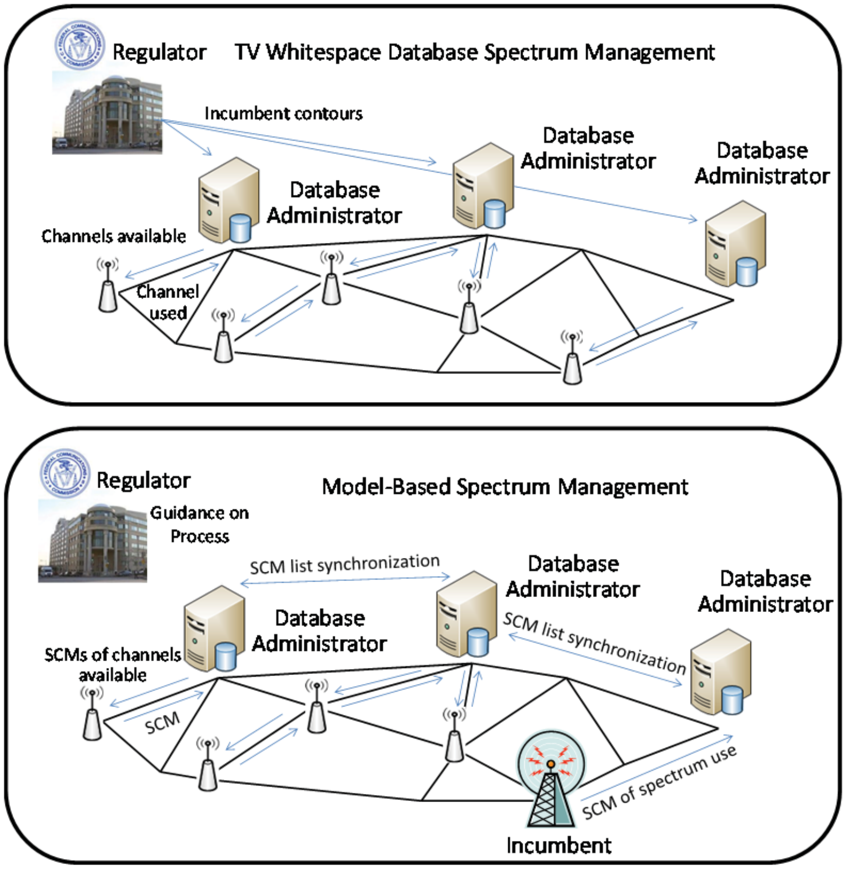

Figure 4. Alternative database spectrum management architectures

22. With the ability to add spectrum to the database and to manage coexistence comes the ability to create spectrum markets. Figure 5 shows that SCM become the part of the communication between owners, exchanges and users identifying the quanta of spectrum owners make available, users request and exchanges authorize for use.

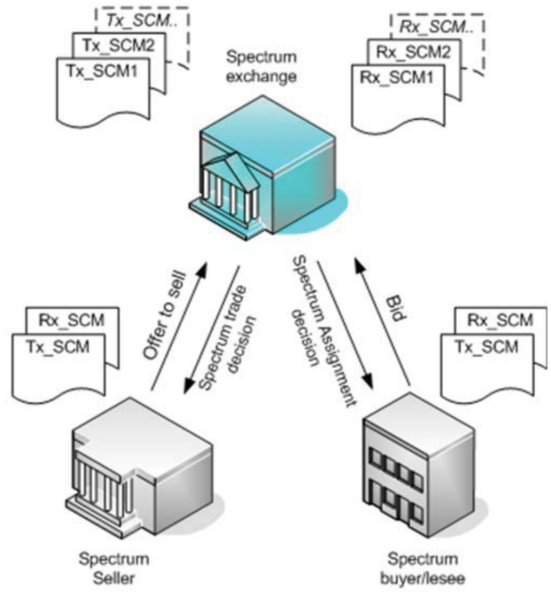

Figure 5. Architecture for a spectrum market using SCM

23. Figure 6 provides the extension of this architecture showing a thriving distributed market where multiple database administrators, a.k.a. brokers, have customers that use their services to find spectrum and where spectrum owners can also work through brokers to provide their spectrum to the market. The brokers use SCMs to communicate the availability of spectrum among themselves.

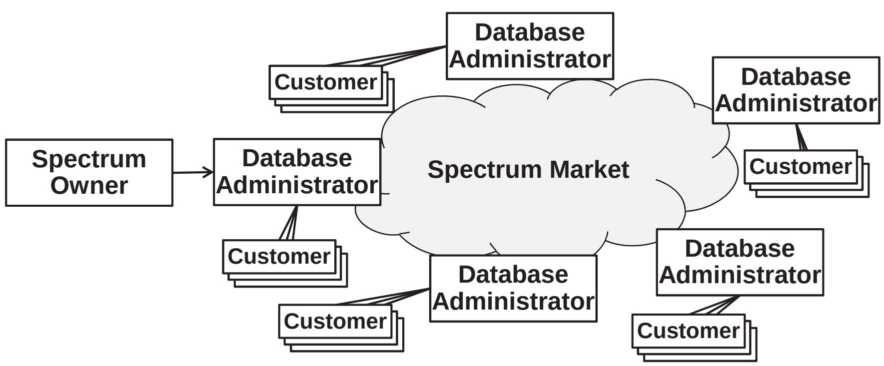

Figure 6. Distributed spectrum market

24. SCM support the negotiation of spectrum use. The idea is simple. Users propose their use of spectrum with an SCM to a spectrum owner who may counter with an SCM of his own anticipated use. The negotiation is centered on refining the SCM until the pair of SCMs are compatible. These, when used with the optional probability data elements that are part of modeling, allow spectrum users to negotiate service level agreements that account for any uncertainty the negotiating parties have in projecting their future use of the spectrum.

25. SCM may also be used as rules governing the behavior of radios and their access to spectrum. SCM can convey spectrum available for use. So long as a radio's use of spectrum is within the boundaries of the SCM it may be used. SCM may also provide constraints. So long as a radio's use of spectrum is compatible with the constraining SCM it meets the constraint. A radio that has self-awareness in the sense of knowing where it is operating and how it would generate its own SCM can use the standard algorithms for computing compatibility to compute whether spectrum is usable by assessing whether its use, as defined by an SCM, is within an authorizing SCM and compatible with any constraining SCMs that it are given as rules.

26. The ultimate architecture links multiple enterprises and supports markets. Each enterprise can have its own business processes and at each interface between enterprises, markets, users, and devices there may be specified data that is provided in addition to SCMs. However, throughout this super-architecture SCMs would provide the common definition of spectrum use and the common methods for arbitrating compatibility.

Effects on Licensing and Band Plan

27. A SAS based on the use of SCM can support any one of the anticipated band plans and licensing schemes proposed in the FCC 13-144. As already described, the SCM can capture the boundaries of spectrum use and be used to prevent new users that would cause interference to systems with localized critical access or which are used under a priority access license (PAL). They can be used as a means to manage coexistence of any systems, between broadband and radar system and even between the unlicensed systems operating in the General Authorized Access (GAA) tier.

28. The SCM can do more. We believe that SCM could readily support the creation of markets which in turn would find the best use of spectrum based on market demands. Potential changes in the proposal that would allow the creation of markets would be to allow all eligible participants to build out infrastructure, not just those who win PALs. All those who build out infrastructure are likely to participate in the market and make it a success. It should encourage incumbents to add spectrum to these markets and to seek opportunities to share it by allowing the market to provide them positive incentives to do so.

29. The IEEE DySPAN-SC plans to provide additional comments on the technical details of the spectrum consumption modeling as part of its response to the Commission's Call for Papers on the Proposed Spectrum Access System for the 3.5 GHz Band.[9]

Conclusion

30. This standards project of IEEE DySPAN-SC Working Group IEEE P1900.5 is directly on point with the objectives of the 3550 – 3650 NPRM. The work promises to create the management capability necessary for a SAS in this band; and, as described, this solution would be a catalyst for innovation in spectrum use and sharing. This standardization work provides the opportunity for industry, federal spectrum users, and government regulators to collaborate in its creation. The working group plans to provide a more detailed description of spectrum consumption modeling in our response to call for papers on the proposed SAS.

Respectfully submitted,

Hiroshi Harada
Chair, IEEE DySPAN Standards Committee
harada@ieee.org, +81-46-847-5074

Matthew Sherman
Chair, IEEE 1900.5 Working Group
shermanmjs@ieee.org, +1-973-229-9520

[9] See DA 13-2213, Wireless Telecommunications Bureau and Office of Engineering and Technology Call for Papers on the Proposed Spectrum Access System for the 3.5 GHz Band, 18 November 2013. Available at http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db1118/DA-13-2213A1.pdf